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Motorola Whitepaper:

Shielding Effectiveness of In-Home Cable TV Wiring and Splitters

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1. Introduction

The purpose of this testing was to characterize the ability of typical in-home CATV cable wiring, connectors and terminations to protect cable TV signals against unwanted interference from fields radiated by consumer TV White Space (TVWS) devices. This protection is called Shielding Effectiveness (SE).

Devices attached to this cabling system will exhibit interference commonly referred to as Direct Pickup or DPU interference. DPU interference is directly related to the shielding effectiveness of the cable, connectors and shielding performance of the tuner of the device attached when in the presence of other radiating devices such as the proposed TV White Space (TVWS) devices. This investigation measured the shielding effectiveness of various cables and connections to determine the impact the proposed TV Whites Space Devices will have on in home CATV reception. Cable systems channelize the full spectrum of their cable plant and try to use all of it to deliver voice, data, and video services to cable subscribers.

This paper does not consider high powered TVWS devices (Class A)[1] as these would not typically be installed by consumers in homes. Since these devices are not in homes there would typically be much greater isolation between most residence CATV wiring and Class A TVWS devices due to distance and other blocking materials between them than there will be between in-home consumer TVWS devices (Class B devices) and the consumer CATV wiring system.

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[1] In a prior Motorola whitepaper, *Recommendations on Cognitive Radio (CR) Operations in TV White Spaces (TVWS)*, Motorola recommended two classes of devices, Class A is a higher-powered geo-location enabled device, suitable for higher power applications such as rural broadband deployment; and Class B devices which are low-power sensing only devices suitable for use in the home.

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2. Shielding Effectiveness Summary

The protection provided by a coaxial cable against radiated fields is called Shielding Effectiveness (SE) and is defined as the difference between the incident electromagnetic field measured in dBV/m and the induced voltage into the cable measured in dBV delivered to a 75 Ohm load attached to the cable.

$$SE \; [dB/m] \;=\; Efield \; [dBV/m] \; - \; Detected \; voltage \; on \; cable \; center \; conductor[dBV]$$

High quality well terminated cables exhibit sufficient shielding effectiveness to prevent interference in fields of greater than 10 Volts per meter [V/m]. However, when cables end in open barrel F-connectors such as unterminated wall outlets and consumer splitters are used, the interference threshold falls to less than 0.3 V/m with some cases seen below 0.1 V/m. In addition, the two samples of older wiring removed from the same home tested with an interference threshold at or below 0.1 V/m.

This test data shows that TVWS devices operating at power levels higher than 10 mW increase the potential for DPU interference into the home cable TV wiring. This same test data also suggests that, if relocating the TVWS device to increase its separation from the cable TV system does not eliminate such DPU interference, then the easiest and lowest cost remediation steps of adding terminations to open cable TV outlets in the home and/or replacing in-room splitters and coax cabling can in most cases improve the interference threshold to a level of 0.3V/m. Additional remediation for DPU issues attributable to in-wall cabling components would be more difficult. As recommended in the prior Motorola whitepaper[2], TVWS devices should be required to implement power control such that they minimize their actual transmit power to the minimum needed to maintain reliable communications in each installation rather than arbitrarily operating at their maximum power levels all the time, and this too should significantly reduce the potential for in home cable system DPU ingress and offers the added benefit of permitting other TVWS devices to operate in closer proximity on the same channel without interfering with each other. And for similar spectral efficiency reasons, consumer TVWS devices should also use protocols designed to minimize the time their transmitters are on regardless of whether such devices are battery operated or connected to a power line.

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[2] In a prior Motorola whitepaper, _Recommendations on Cognitive Radio (CR) Operations in TV White Spaces (TVWS)_, Motorola recommended TVWS devices be required to implement automatic power control to minimize overall system interference levels.

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3. Field Strength

For reference, a plot of Field Strength as a function of open space distance from the radiating signal source is provided in Figure 1, below. The power levels plotted are those proposed for portable TVWS devices as well as the Motorola proposed consumer device power limit of 10 mW or 10 dBm EIRP.

Also plotted in Figure 1 is the current FCC immunity requirement for Cable Ready Devices as specified in 47CFR15.118 at 0.1 V/m (dashed red line). The typical interface threshold seen in this cable and splitter testing is represented by the dashed yellow line (0.3 V/m).

For example, a TVWS device transmitting at 10 mW (blue line) will typically not cause DPU interference in a cable TV system if it is located more than 6 feet and with an interference threshold of 0.3 V/m or more than 18 feet with an interference threshold of 0.1 V/m. However, a 100 mW TVWS device (pink line) would typically need to be over 19 feet away from the cable TV system with an interference threshold of 0.3 V/m, which exceeds most room sizes, in order to avoid DPU interference.
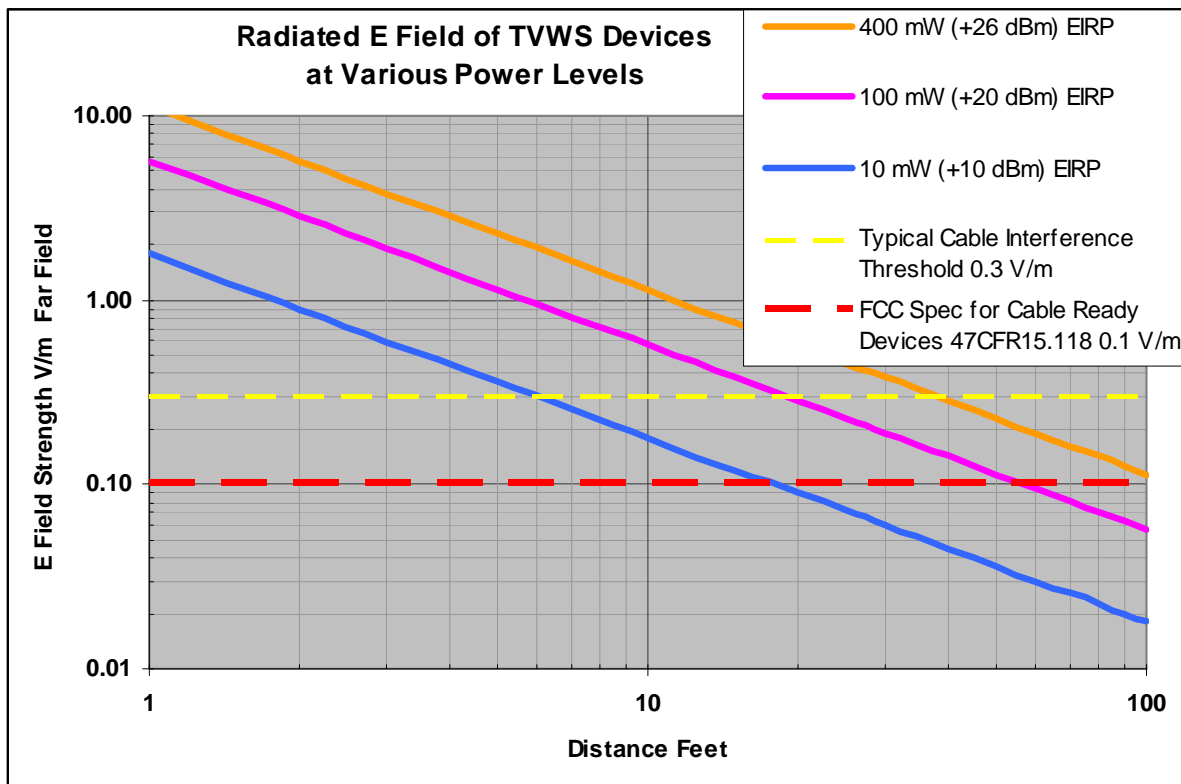

Figure 1 - Field Strength as a Function of Distance

Since this analysis is focused on the potential for in-home direct pick up interference of TVWS devices into the cable TV wiring, splitters and connectors, it is important to consider not only the overall size of residences, but also of individual rooms. Cable TV wiring frequently runs through many rooms and is often installed within the walls. In newer construction, there are often wall plates in most rooms with open F-connector barrels to enable easy consumer connection to the cabling system; DPU ingress picked up anywhere in the home cable system will be carried throughout the home.

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4. Methodology

4.1. Use of the Absorbing Clamp

The method used for testing the shielding effectiveness of the cables and connectors was adapted from CISPR 20/EN 55020:2002 Section 5.5 and involves directly injecting RF currents onto the shield of the cable or device under test through the measurement port of an Absorbing Clamp. Signals that leak through the cable shield and/or connection and are induced into the cable are measured by a receiver connected to the cable output. These induced signals are measured directly across the entire frequency range of interest in one sweep. This method allows for rapid evaluation as well as a high degree of repeatability.

Correlation of this measurement was performed by comparing a few special cases to that measured in a semi-anechoic chamber using a constant swept field.

4.2. Calculations

Measured shielding effectiveness is calculated as:

$$SE = 20Log(F) + Absorbing\ Clamp\ Result - 16$$

Where:

SE = Shielding effectiveness in dB

F = frequency in MHz

Absorbing Clamp Result = the measurement defined in 3.3.2 below

16 = an empirically determined constant relating electric field to RF induced current on a length of cable (See Appendix I for derivation).

Using this value of shielding effectiveness, the threshold of interference was calculated as:

$$InterferenceThreshold[V/m] = 10^{(\frac{SE-100}{20})}$$

Where the 100 dB corresponds to the SE value needed for the threshold of interference to 256 QAM DTV signals at the minimum FCC required level of -12 dBmV at an applied field of 1 V/m (See Appendix I for derivation).

4.3. Test method

4.3.1. Setup

The cable and termination under test was placed at one end of a 4 meter long non-conductive table, 80 cm above the ground. The cable was laid out along the length of the table and was attached to a receiver through an appropriate impedance matching network. The absorbing clamp was placed around the cable with the current transformer end toward the termination or DUT, i.e. away from the measurement receiver. The RF input of the absorbing clamp was attached to an RF tracking generator.
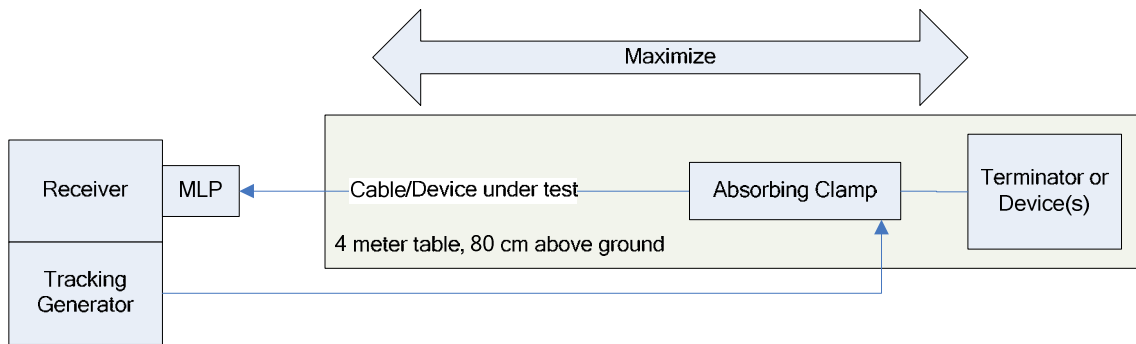
Figure 2 - Test Setup.

4.3.2. Measurement Procedure

With the cable under test arranged as described above, the receiver was set to record Max-Hold over the frequency range of 50 to 850 MHz and the absorbing clamp was moved slowly along the length of the cable under test. This data was recorded as the Receiver Trace in dBuV. The receiver trace was corrected using:

$$\textit{Absorbing Clamp Result = Direct – Insertion Loss – Receiver Trace + Cable Loss}$$

Where

Direct = Tracking generator output connected to receiver input in dBuV, straight through case

Insertion Loss = calibration data from absorbing clamp in dB (nominally 17 dB)

Cable loss = measured loss of the cable under test in negative dB

Note: For expedience, the cable loss was measured for the reference cable and this value was used for all remaining cases.

Short cables were tested by attaching them to the reference cable using a high quality barrel during test. Splitters and other terminations were attached to the reference cable.

4.3.3. Test Cases

- High quality cable and connector used as a reference case

- Various terminations of the Reference cable

- Consumer and professional splitters

- Various terminations of splitters

- Cables purchased at national chain stores

- Professionally made cables, various cable types and connector types

- Wear Cases – used and worn cables removed from a home and limited bend cases on a good cable

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5. Test Results

The testing was performed 9/11/07 through 9/12/07.

5.1. Graph Key:

The key shown on each graph identifies the test devices. For cables, the key also identifies the length and type of coax as well as the type of shielding as identified here:

- Ref – reference cable

- QS – quad shield

- DS – dual shield

- SS – single shield

- ?S – unknown shield

- S1, S2… – splitter #1, #2

- RG59 – RG 59 Cable

- RG6 – RG6 cable

- HEC – Commscope Head End Cable

Other notes in the key describe the connector style (HEX crimp, Snap-n-Seal, conical, etc.) and information about the presence of barrels, terminations, etc. More detail is provided in the description of each test and its corresponding graph.

5.2. Interpretation of the Graphs

The left side vertical scales are the measured Shielding Effectiveness of the cable assemblies in dB. A value of 120 dB indicates 20 dB BETTER shielding effectiveness compared to 100 dB.

The right side vertical scales are the corresponding calculated TVWS device radiated field strength at the cable, splitter, or port that correspond to the Interference Threshold in V/m for a 256 QAM cable system operating at -12 dBmV.   A cable with better shielding effectiveness can protect against a higher incident field. For example, a cable assembly with SE = 100 dB can protect against a TVWS device with a radiated field strength at the cable of 1 V/m. See Appendix 1.

The horizontal scale is the operating frequency in MHz.

For example, in Figure 3 below, the yellow trace that corresponds to the reference cable with a barrel connector attached but unterminated shows that at 200 MHz, it exhibits a shielding effectiveness of 90 dB (left axis). This corresponds to a TVWS device radiated field interference threshold of 0.3 V/m (right axis).

If this sample cable was used for in -home wiring of a CATV connection, DPU interference from a TVWS device would occur if the field strength at the cable radiated by the TVWS device was 0.3 V/m or greater.

5.3. Reference Cable and Termination Variants

A high quality quad shielded RG6 cable was chosen as the reference cable. This cable exhibited better than 120 dB SE over most of the frequency range of interest and measured at essentially the detection system noise floor. In order to establish the impact of the cable termination, the following cases were chosen:

- Good termination, high quality barrel – represents the best case termination of the cable
- Noise floor – detection system noise floor with no cable in the clamp
- Push-on style connection with high quality barrel
- Push-on style connection with consumer grade plated barrel
- Reference cable terminated into barrel only – simulates unused wall outlet
- Reference cable unterminated

It can be seen in Figure 3 that the shielding effectiveness of even a high performance cable can be significantly degraded by the quality of the connecter and termination. The common barrel terminated case which represents the typical unused cable TV wall outlet degrades the mid-band SE from 130 to 90 dB and results in a system interference threshold of about 0.3 V/m.

This indicates that even if the home is wired with good quality cable, the common practice of leaving unused cable outlets unterminated causes significant degradation to the shielding effectiveness of the system.
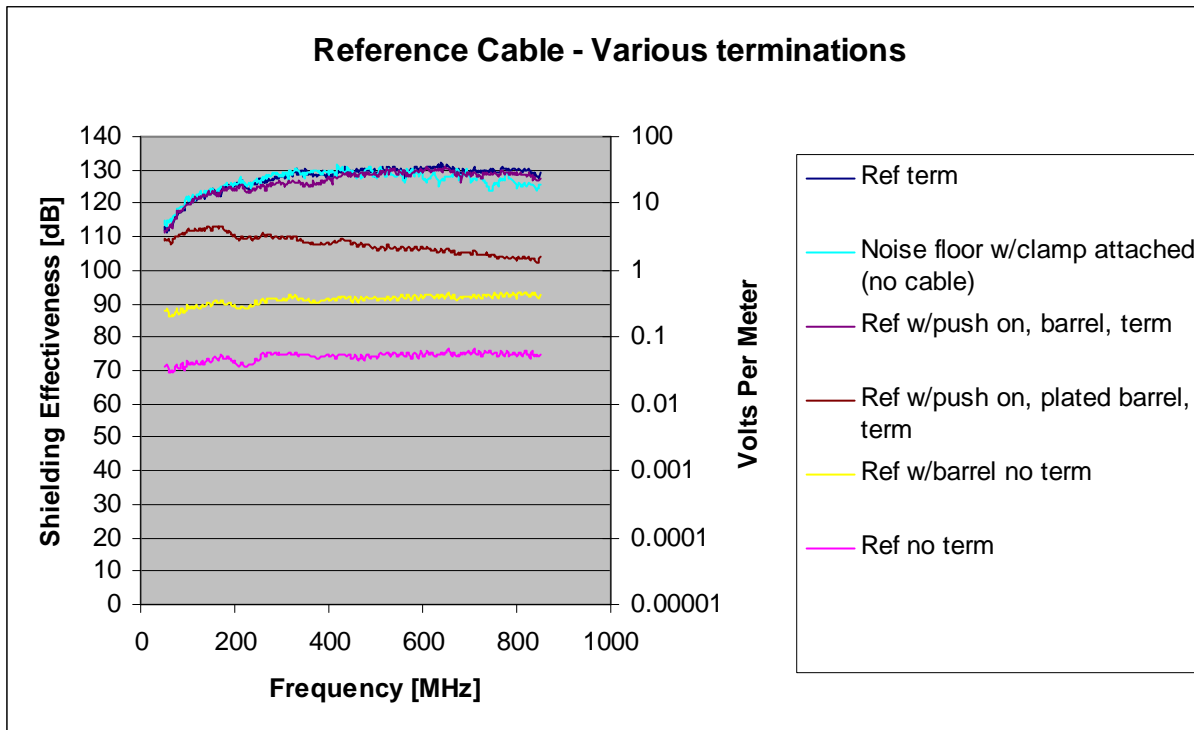

Figure 3 - Reference Cable Test with Various Terminations

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5.4. Splitters and Termination Variants

Four consumer grade (S1-4, all available models purchased from three local national retailers just prior to testing) and two professional grade (S5-6, one installed by the local cable company and one found in a Motorola cable TV lab) two-way splitters were attached to the Ref cable and tested with:

- Both ports terminated

- Both ports unterminated

- One port terminated and one port connected to a six foot cable which was terminated with a barrel. This case represents an in-wall splitter connected to a receiver with the other port going to an unterminated wall outlet.

The both ports terminated results in Figure 4 show mid-band SE variations of up to 50 dB with the worst case interference threshold of 0.1 V/m. The results shown in Figure 4 reveal that the professional grade splitters perform substantially better than any of the consumer grade splitters. Note that all the consumer grade purchased splitters had glued backs while the professional splitters had soldered backs.

The unterminated results shown in Figure 5 degraded the good splitters performance resulting in poor average interference threshold. And the results shown by the test condition of Figure 6 is representative of an unused cable TV wall outlet in a home, although the wire in the home may be longer than 6' depending on where the splitter is installed in that scenario.
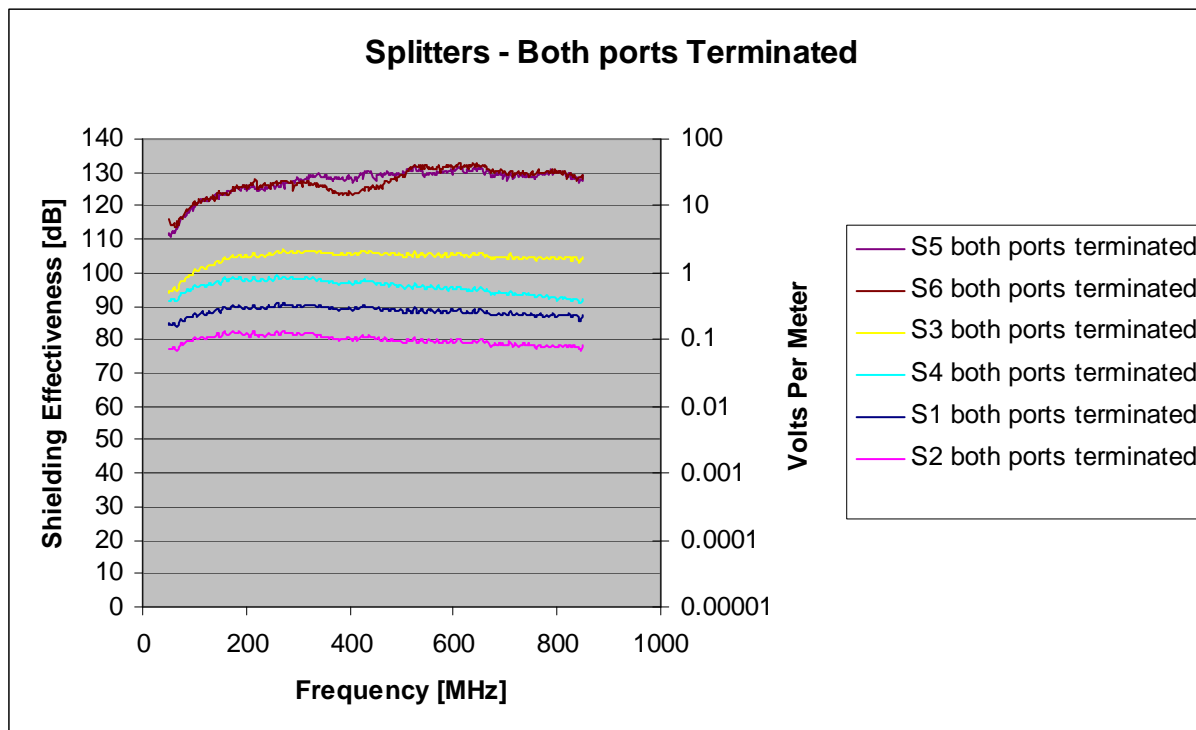
Figure 4 - Two-Way Splitters with Both Ports Terminated

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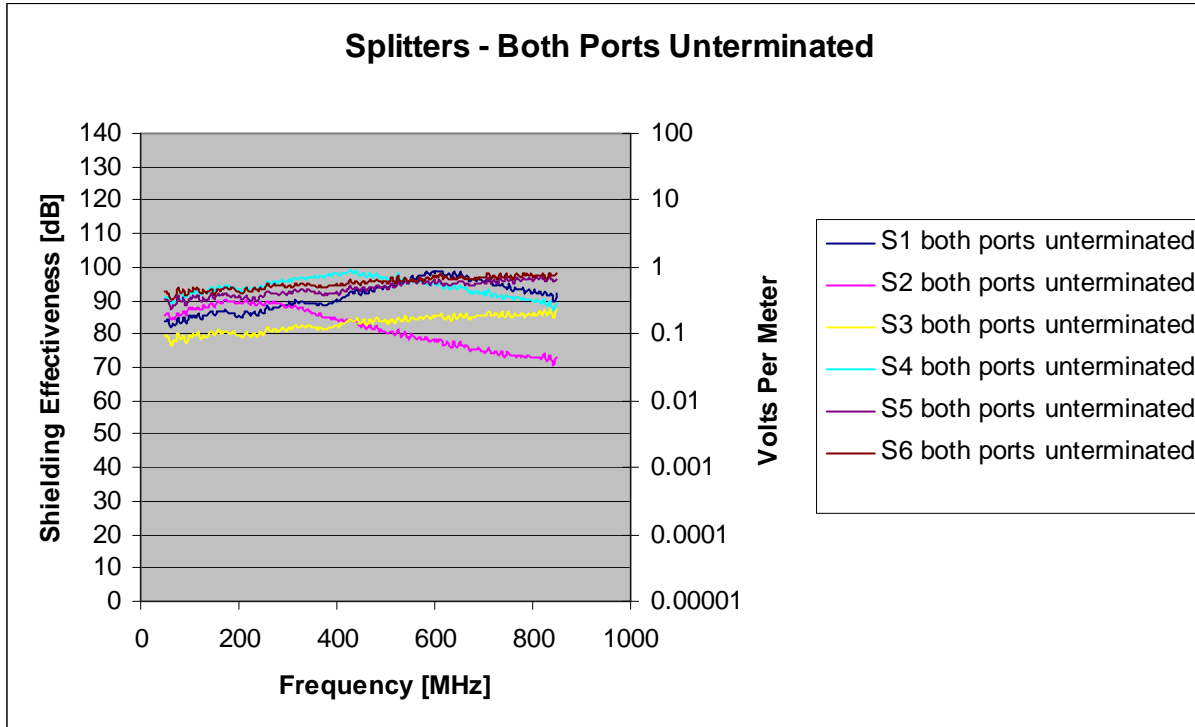101 Tournament Drive
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Figure 5 - Two-way Splitters with Both Ports Open
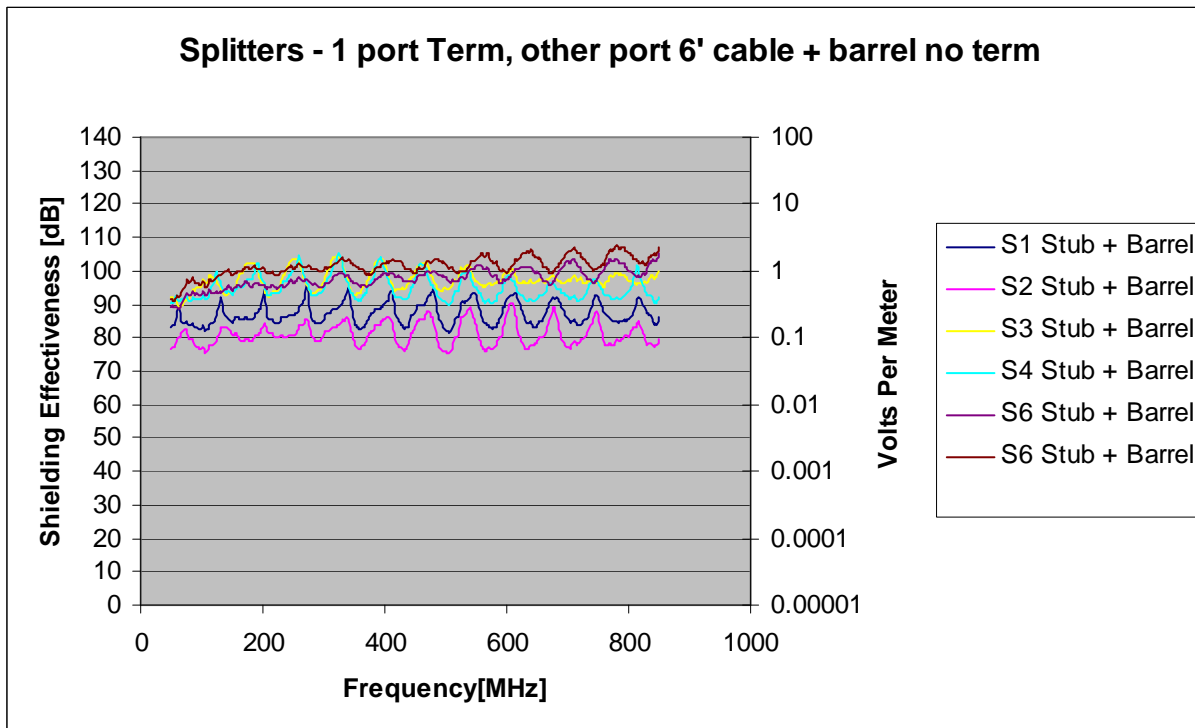
Figure 6 - Two-way Splitters with One Port Terminated, Second Port Attached to 6' Cable and
Barrel and Open (No Termination)

5.5. Retail Purchased Cables

A number of coax cables were purchased from local national chain retailers to represent what the consumer may find readily available. Figure 7 show the high quality, quad shield RG6 cables performed as well as the Ref cable (Figure 3) while the others had up to 50 dB variation in SE. This resulted in an average interference threshold of about 3 V/m and a minimum of about 0.1 V/m.

Figure 7 - Retail Purchased Cables

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5.6. Professionally Made Cables
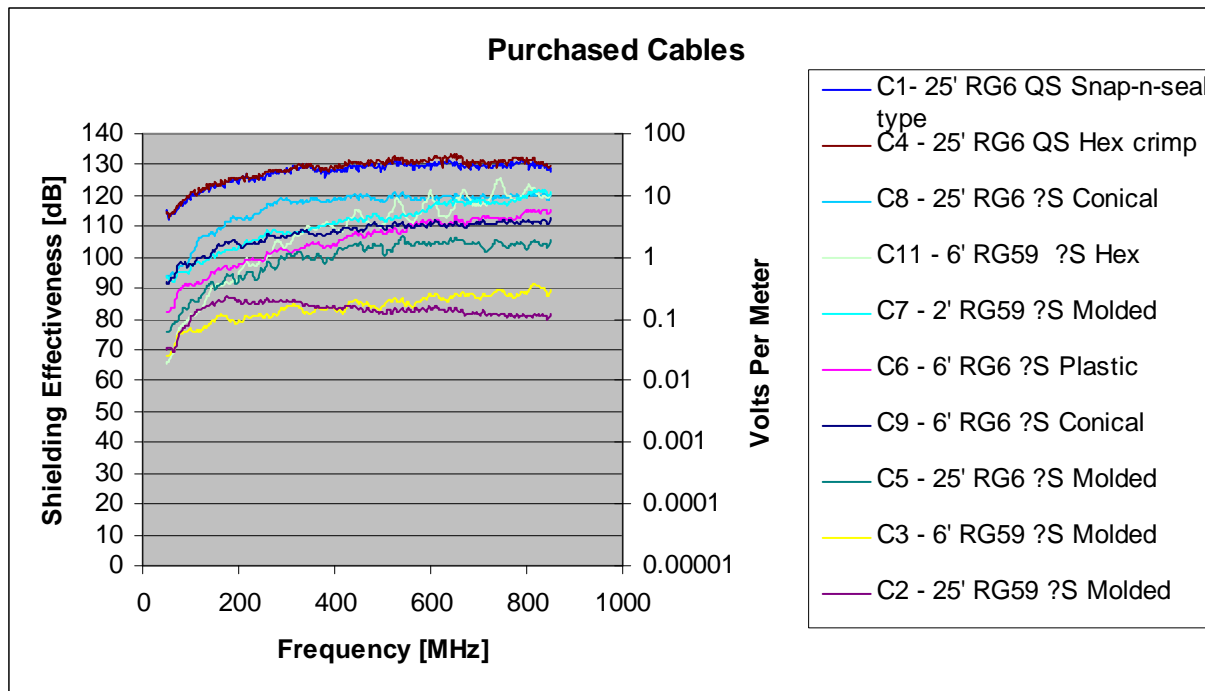
In order to evaluate basic cable type and connector type differences we had a number of cable assemblies professionally assembled by a skilled technician:

- RG6, quad shield (QS)

- RG59, dual shield (DS)

- Commscope HEC

- RG59, single shield (SS)

For each type of cable, four connector types were evaluated: Ribbed HEX, Conical HEX, HEX, Snap-N-Seal, ribbed conical (Refer to photos).

As shown in Figure 8, the RG6 quad shield and HEC cable were the top performers having a SE of about 130 dB. The RG59 dual shield was about 10 dB worse followed by a grouping of RG59 dual or questionable shield about 15 dB below that and finally RG59 single shield 30 dB below that. Here again we have a range of performance of about 55 dB with a minimum interference threshold of less than 0.1 V/m.

There were no discernable differences in connector style performance except for cables 15 and 27 which had poorly fitting HEX crimp connectors that were intended for larger coax cable types (see photos in Appendix II).

Professionally Made

Legend:
- C14 - 20' RG6 QS Hex
- C16 - 20' RG6 QS ribbed Hex
- C13 - 20' RG6 QS Conical
- C10 - 20' RG6 QS SNS
- C18 - 15' HEC ?S Conical
- C17 - 15' HEC ?S Hex
- C12 - 13' HEC ?S SNS
- C26 - 12' RG59 DS Conical
- C25 - 14' RG59 DS rib Conical
- C24 - 18' RG59 DS Conical
- C23 - 20' RG59 DS Rib Hex
- C27 - 20' RG59 DS Hex
- C15 - 12' RG59 ?S Hex
- C20 - 20' RG59 SS Hex
- C19 - 20' RG59 SS SNS
- C21 - 20' RG59 SS ribbed Hex
- C22 - 20' RG59 SS Rib Conical

Figure 8 - Professionally Made Cables

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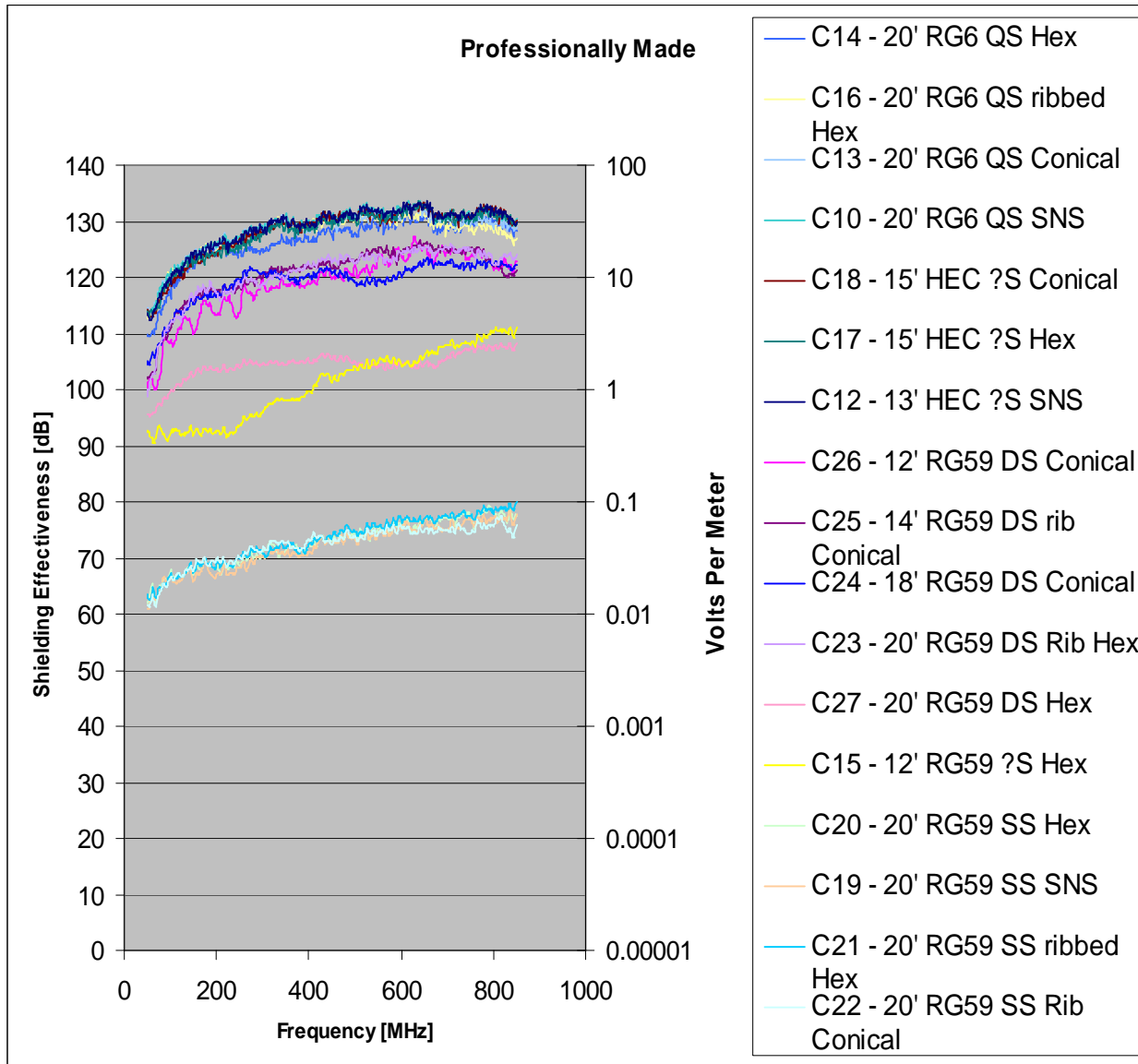## 5.7. Wear Test Cases

A few cases of wear were evaluated to determine the impact of age and use degradations:

- RG59 cable with dual shield, kink in cable, bent 10 times at the connector, and bent 60 times at the connector

- Two cables that had been removed from a house, an RG59 cable type with unknown shielding construction and an estimated age of 20 years. These cables were originally installed by the local cable TV company.

- An additional measurement run on the longer house cable near a break/tear in its shield.

The results are plotted in Figure 9. Bending the good cable resulted in a degradation of about 10 dB at the higher frequencies. The used cables from the home had mid-band interference thresholds of about 0.1 to 0.5 V/m with worse performance below 200 MHz.
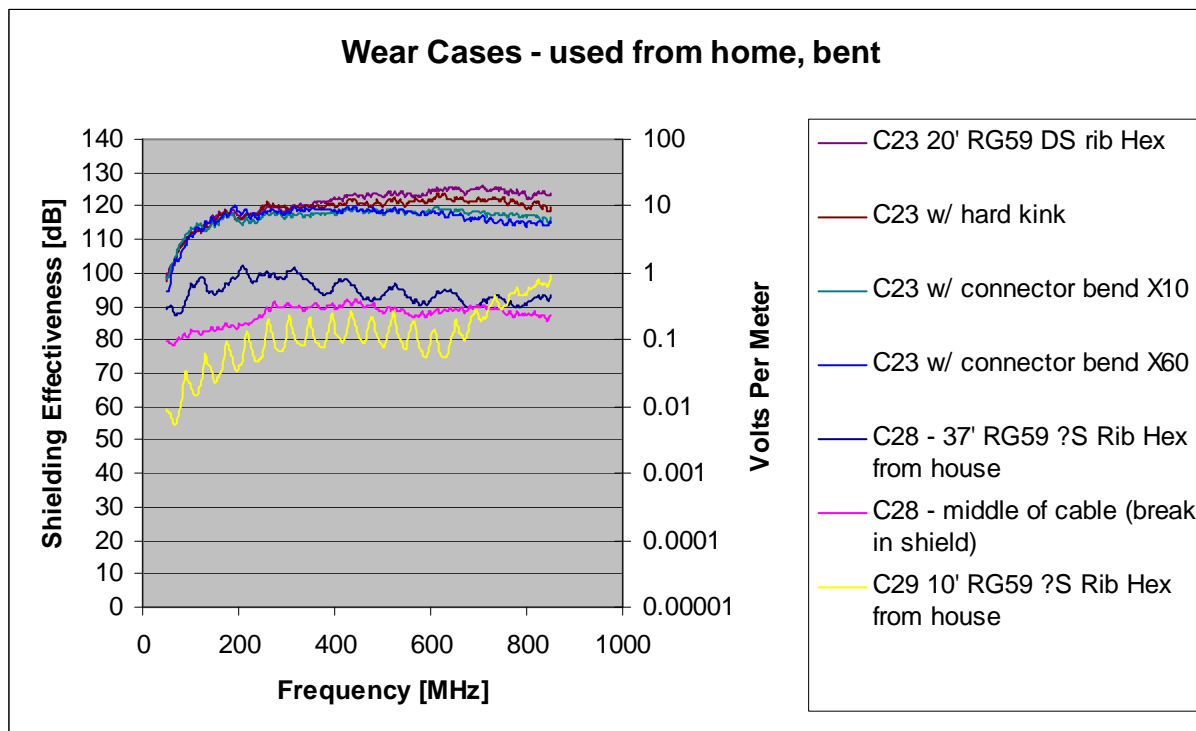

Figure 9 - Cable Wear Test Cases

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6. Conclusion

These tests show that high quality well terminated in-home cable systems can perform very well and exhibit sufficient shielding effectiveness to prevent interference in the presence of fields greater than 10 Volts per meter [V/m]. But it also showed that, when cables that end in open barrels such as unterminated wall outlets and consumer grade splitters are used, the interference threshold typically falls to 0.3 V/m with some cases seen below 0.1 V/m. In addition, with older cable samples from one home and some poor quality connections, interference thresholds were seen at or below 0.1 V/m.

The same test data also indicates some of the potential remediation solutions that can be used in a home should DPU interference from a TVWS device occur. The least expensive and easiest solution is to move the TVWS device farther away from any cable TV wiring in the home, thereby lowering its incident E-field on the cable TV wiring. Additionally, if TVWS devices automatically adjust and limit their transmit power to the minimum level required to maintain the link to the intended receiver, this will also reduce cable DPU issues as well as potential interference with nearby TVWS devices operating on the same frequency.

Table 1 illustrates this in a tabular format. Three potential consumer TVWS transmit power levels are shown against two test cases. The first test case is set at the cable ready TV DPU threshold of 0.1 V/m, which would also be representative of poor cable wiring as shown in this test report. The second test case is at a threshold of 0.3 V/m which is representative of the typical test cases seen in this report. The resulting distances can be mapped into residential properties and compared to typical dwelling room sizes. In many homes and apartments, cable TV wiring is present in most or all rooms of the dwelling such that the achievable separation may be the distance to cables behind the nearest wall, floor, or ceiling.

TVWS Device Tx Power	Minimum Required TVWS Device Separation from home cable wiring system with 0.1 V/m threshold (FCC-compliant TV receiver threshold)	Minimum TVWS Device Separation from home cable wiring system with 0.3 V/m threshold
400 mW	114 feet	38 feet
100 mW	57 feet	19 feet
10 mW	18 feet	6 feet

Table 1 - Distance vs. Tx Power for Two In-Home Scenarios

This testing also suggests the remediation required to improve many poor systems from an interference threshold of 0.1 V/m to 0.3 V/m is achievable at low cost and effort by adding terminations to open barrels in the home and/or improving the quality of the in-room cables and splitters. In the current retail market the difference between good and poor quality cable TV components is based on the electrical construction of the equipment and not the physical look. As an example of this, note that three of the four retail purchased two-way splitters that did not perform well were gold plated (see Appendix II, photo of S1, S2, and S3), while the better performing professional grade devices were not gold plated but had soldered backs.

Many homes have been constructed with in-wall cable distribution systems and these would be the most difficult and expensive to remediate. This is because such efforts will require fishing new wires and opening walls in some cases to access buried splitters and connectors. This may be more of an issue in shared dwellings such as apartments, condos, and town-homes as

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compared to single family houses since there may be cabling devices in the shared walls and the DPU interference may be caused by a neighbor's TVWS device.

In a prior Motorola whitepaper, _Recommendations on Cognitive Radio (CR) Operations in TV White Spaces (TVWS)_, Motorola recommended a consumer (Class B) TVWS device power limit of 10 mW (10 dBm EIRP). This power level was arrived as a recommended balance between enabling this new class of useful consumer devices while minimizing the potential for interference to the existing widely deployed cable TV service. This recommendation was derived from this test data that shows TVWS devices operating at power levels much greater than 10 mW in the consumer environment significantly increases the potential to cause DPU interference into the home cable TV wiring in many cases. While a potential exists for DPU interference in some situations even with consumer TVWS devices operating at 10 mW, as shown here, Motorola believes that these should typically be solvable at little to no cost and effort by actions that consumers can take.

Appendix I – Theoretical Considerations

Calculation of radiated field strength interference threshold from shielding effectiveness

Using the FCC minimum CATV power level of -12 dBmV or 48 dBuV and a C/I ratio of 27 dB for the threshold of interference for 256 QAM, an induced interference voltage threshold of 48 – 27 = 21 dBuV is needed to disrupt a 256 QAM digital CATV channel.

Shielding effectiveness as used in this report is defined as:

$$SE\ [dB/m]\ =\ Efield\ [dBV/m]\ -\ Detected\ voltage\ on\ cable\ center\ conductor\ [dBV\,]$$

Or

$$SE = E - V_D \quad [1]$$

Therefore, with an incident radiated field of 1 volt per meter (120 dBuV/m), the SE would have to be better than 99 dB to prevent interference. Thus 100 dB SE corresponds to the minimum shielding effectiveness required to prevent interference at 1 V/m. Similarly, a SE of 120 dB is required at 10 V/m and so on.

Derivation of shielding effectiveness from cable induced current

The absorbing clamp method outlined herein measures shielding effectiveness indirectly by measuring the induced voltage into the load attached to the cable assembly under test due to the RF current injected onto the outside of the shield by the current transformer in the absorbing clamp. Note that the current transformer portion of the absorbing clamp is used to INJECT a current onto the outside of the shield of the coaxial cable assembly under test. In order to determine the value of SE, the relationship between the incident electromagnetic field and the induced shield current must be determined.

The shield of the cable under test may be considered as an antenna with the general characteristics as follows:

$$Antenna\ voltage\ [dBV] = Field\ Strength\ [dBV/m] – 20log(F[MHz]) + 10log(g) +29.8 \quad [2]$$

Where:

F = frequency in MHz

g = numeric gain of the antenna

The shield or antenna current then would be this voltage divided by the impedance of the antenna or radiation resistance R (ohms):

$$Antenna\ Current\ [dBA] = Field\ Strength\ [dBV/m] - 20log(F[MHz]) + 10log(g) + 29.8 - 20log(R)$$
$$[3]$$

If the gain and radiation resistance are assumed to be independent of frequency, this can be reduced to:

$$\textbf{Antenna Current [dBA] = Field Strength [dBV/m]} - \textbf{20log(F[MHz]) + K} \quad \textbf{[4]}$$

Where K represents the sum of the unknown gain plus radiation resistance plus 29.8 as shown in equation [3].

The experimental absorbing clamp measurement is:

$$Absorbing\ Clamp\ Result = Direct - Insertion\ Loss - Receiver\ Trace + Cable\ Loss \quad [5]$$

Where:

Direct = Tracking generator output connected to receiver input in dBV, straight through case

Insertion Loss = calibration data from absorbing clamp in dB (nominally 17 dB)

Cable loss = measured loss of the cable under test in negative dB.

The first two terms are equal to the current injected onto the cable shield, I_C and the second two terms are the induced voltage, V_D. Thus the calculated value returned in the test is:

$$\textbf{Absorbing Clamp Result} = I_C - V_D \quad \textbf{[6]}$$

Using equation [1]:

$$SE = E - V_D$$

Substituting V_D from [6] gives

$$SE = E - [I_C - Absorbing\ clamp\ result]$$

Substituting I_C or antenna current from [4] gives

$$SE = E - [E - 20log(F) + K - Absorbing\ clamp\ result]$$

or

$$\textbf{SE = 20log(F) + Absorbing clamp result} - \textbf{K} \quad \textbf{[7]}$$

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Determination of the field to clamp correction factor, K

In order to determine the factor K, three cable samples of various SE were tested, both in a semi-anechoic chamber using a constant E field strength and then also with the absorbing clamp method. Using these three sets of data, the experimental value for K was determined.

First, the semi-anechoic chamber was calibrated to a 10 V/m (140 dBuV/m), horizontally polarized electric field over the frequency range 50-850 MHz. Calibration was performed using an isotropic field probe at the center of a 1.5 meter wide non-conductive table 80 cm above the ground plane.

The three cable samples tested were a quad shield RG6 cable referred to as the REF cable as the representative high SE case; a 1.46 m length of RG59 coax shield connected to the center conductor of the ref cable as the unshielded case; and a 1 m jumper with poor crimp connectors into 75 ohms attached to the end of the REF cable as the medium SE case.

Each cable was placed across the test table with the terminating end stopping at one table edge and the other end dropping to the ground, through a ferrite tube and exiting the chamber where it was monitored with a spectrum analyzer.

During the Application of the 10 V/m field, the receiver was set to max-hold mode to capture the detected voltage across the frequency range. Shielding effectiveness was then calculated directly per [1] above:

$$SE = E - V_D + Cable\ loss$$

Where

E = field strength in dBuV/m

V_D = voltage induced and detected at the receiver in dBuV

Cable loss = loss of the REF cable from the chamber to the receiver in dB

Each cable sample was then retested using the absorbing clamp method previously described and corrected according to [7] above.

The "best fit" value of K was then determined from this data to be **16 dB**.

Figure 10 compares the shielding effectiveness determined by the direct radiation in the semi-anechoic chamber procedure and the model corrected absorbing clamp procedure. In the 'no shield' and 'poor shield' sample cases the model correlates very well with the anechoic chamber data. In the case of the REF cable, it should be noted that both of these measurements were at or near the noise floor of the measurement system introducing error. Even with this error, the correlation is high.
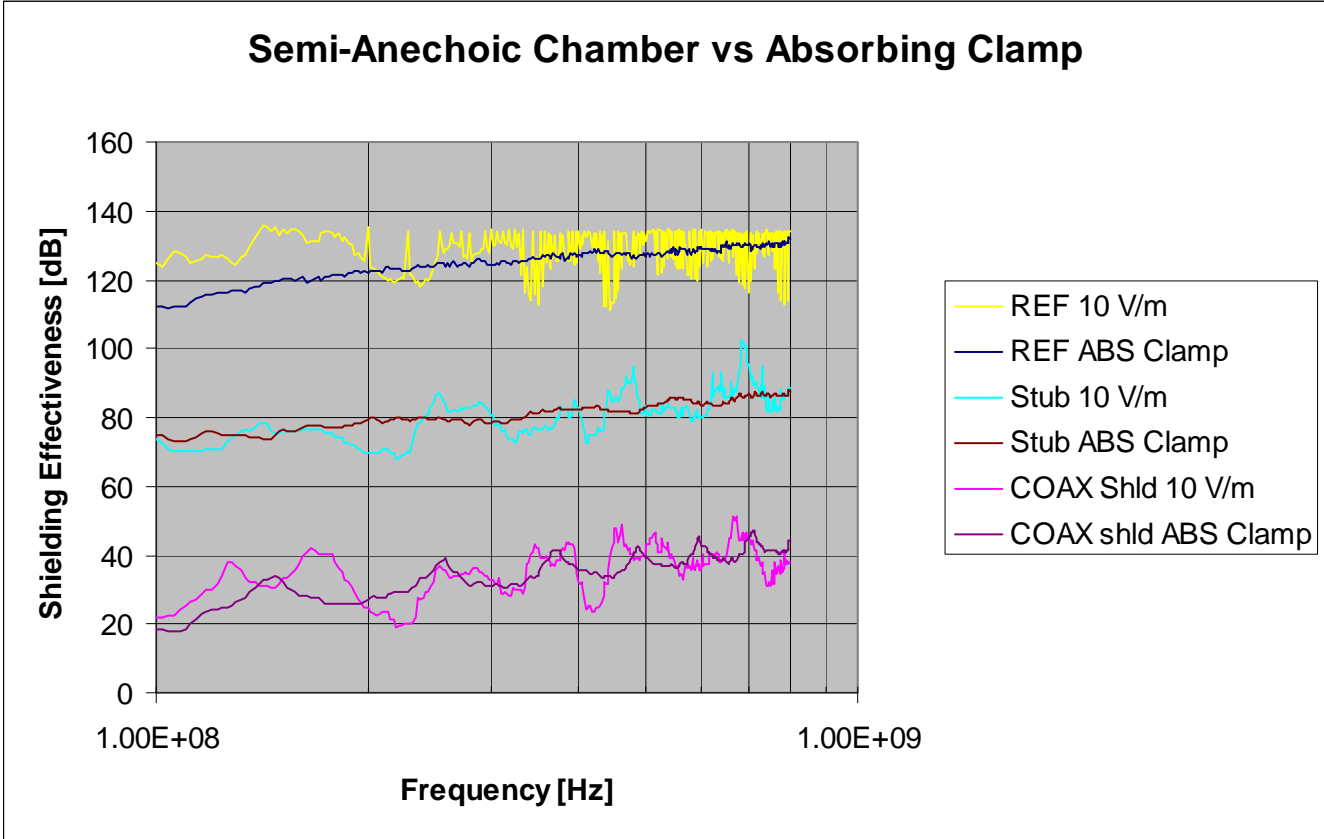
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Figure 10 - Semi-Anechoic Chamber vs. Absorbing Clamp Correlation

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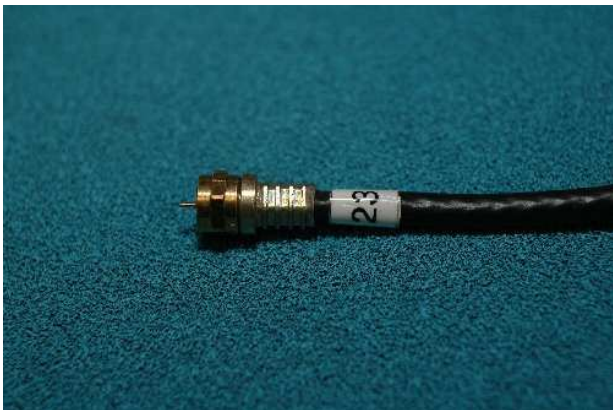101 Tournament Drive
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Appendix II – Test Sample Photographs

The numbers shown on each cable and splitter in the figures below correspond to the numbers shown in the keys for Figures 4 – 9.

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Appendix III – Test Equipment

Test Equipment:

Manufacturer	Description		Model	Calibration Due Date
Hewlett Packard	EMI Receiver		8546A	3/29/2008
Hewlett Packard	Amplifier		8447F OPT010	NCR
Rohde & Schwarz	Absorbing Clamp		MDS 20	6/14/2008
Hewlett Packard	Signal Generator		E4438C	8/14/2008
Amplifier Research	Field Monitor		FM5004	NCR
Amplifier Research	Field Probe		FP5000	10/9/2007
Amplifier Research	Amplifier 80MHz-1GHz		250W1000A	NCR
Boonton Electronics	Power Sensor		51011-EMC	9/29/2007
Boonton Electronics	Power Meter		4532	9/29/2007
Wearlatone	Directional Coupler		3910	9/29/2007
EMCO	Antenna		3143	NCR
Fischer	Absorbing Clamp		F-201-23mm	2/19/2008

MOTOROLA

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